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Experimental Investigations on Wick Irrigation: An Indigenous Irrigation Technique to suit Small-land holders

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Abstract —*The study presents details of experimentation on an unfavourable land with 'Wick Irrigation' using adverse quality of water. Saline water was used for irrigation for growing horticulture crops on alkaline farm without using any type of fertilizer. Wick Irrigation was compared with the farmers' regular method of hand watering with basin irrigation. Wick Assemblies were prepared by installing cotton wicks into the plastic canes of 10 liters and 5.5 liters. Small and Large 'Wick Assemblies' 24 Nos. each were installed at centre-to-centre distance of 1.5 m on the field. Seeds of Tomato (Solanum lycopersicum) and White Kidney beans (Phaseolus vulgaris) were planted around the small and large 'Wick Assemblies' and 9 Nos. of basins. Water application and Yield of individual 'Wick Assembly' was observed. To study moisture distribution around 'Wick Assembly' open pit method was employed. Benefit-Cost calculation was also performed. When compared to basin method of irrigation the increase in yield for small 'Wick Assemblies' was 27.30 % and for large 'Wick Assemblies' it was 54.6 %. The moisture movement was more vertical than horizontal. The wetting pattern was resembling to a balloon and spread to a horizontal distance of 21 cms and to a depth of 68 cms from the GL which is widely accepted as an effective zone for drawing out of moisture from the soil by the plants roots. The Benefit-Cost ratio per acre as compared to conventional farming for small 'Wick Assembly' was found to be 1.93 and that for large 'Wick Assembly' is was 2.34. In view of the fact that this technology uses very less water it has a great potential for gaining popularity among farmers particularly in regions with scarce water. This technology does not call for any technical skill for its operation and maintenance. Adoption of this technology greatly enhances the economic benefit of the system and thus would also help uplift the farmers' economic condition. However, large scale adoption of wick irrigation is laborious. As the water requirement for wick irrigation is very small it can be taken care of by rain water harvesting. The use of wick irrigation is only applicable to small-scale agriculture. Wick irrigation is ideal for small farmers living in remote areas where vegetables are expensive and hard to come by. The experimentation confirmed the fact that this indigenous method can be successfully employed even for unfavourable land and water*.

Keywords- *Micro-Irrigation, Wick Irrigation, Rain Water Harvesting, Sustainable Small Scale Irrigated Agriculture, Water Management. Wetting Front Advancement.*

I. INTRODUCTION

India by-and-large depends on agriculture for livelihood. In India rain-fed areas that do not have any irrigation amenities accounts for 60 % of the cultivated areas [1] and these areas are also home to majority of rural poor and marginal farmers of the country. The major problems that pose threat to the sustainability of the irrigated agriculture are low irrigation efficiency, high saline irrigation Water, heavy soil texture, and lack of adequate field drainage systems [2]. The currently marketed technologies such as Drip Irrigation is more suited for large fields and in fact is extremely sophisticated and expensive and thus impractical for farmers trying to eke a living out of their very small land holdings consequently, low cost systems those are technically less confusing and uncomplicated should be designed to suit the small and medium farmers who represent a very large number of farmers in India [3]. Water conservation in agriculture with due consideration for its sustainability that is affordable by small farmers will address both the issues of water scarcity and the problems of small and medium farmers. One way of doing this is to explore engineering options for producing more crop per drop using 'Wick Irrigation'. Wick systems have been used in India in conjunction with buried clay pot irrigation. A hole or holes are punched in the buried clay pot and a porous wick made of cotton is inserted in the hole. The material wicks the water from the container into the soil and provides a slow steady source of water to encourage root development and plant growth [4]. Joseph Kamalam (2011) has carried out experiments on 'Wick Irrigation' during the past many years [5]. Experiments carried out by Ferrarezi et al (2016) suggests that 'Wick Irrigation' can be effectively employed in the regions having high temperatures, limited man power and electrical power. It is believed that this can be achieved by encouraging the farmers to take up cheap indigenous methods such as wick irrigation as an alternate to Drip of Sprinkler irrigation which are mostly useful to large fields and are in fact sophisticated technologies. It was thus felt necessary to carry out investigations on wick irrigation for practical implementation for water scarce areas such as Surendranagar District.

II. EXPERIMENTAL SECTION

2.1. Location

For the purpose of carrying out an experimental investigations on 'Wick Irrigation' a farm located at village Jeeva near Dhrangadhara City was selected. The experimental farm is approximately 25 Kms. from the Dhrangadhara city of Surendranagar district of Gujarat. The district is situated between the central regions of Gujarat, in the Saurashtra peninsula. The maximum temperature is 45.6 degree centigrade and the minimum temperature is 7.8 degree centigrade. The average rainfall in the district is 450 millimeter. The geographical area of the district is 10,489 Square Kilometer. The district comprises of 10 taluka. Surendranagar District is having neutral soil. Electrical conductivity of the soil is low. Organic carbon, nitrogen and phosphorus content of the soil are also low. Potash is high. As a result on the whole, the soil fertility indices are not good from the point of view of agriculture [5].

2.2. Experimental Set-up

For obtaining a good tilth the land was prepared by tractor. Later, the same process was repeated 3 times so that the land may have good aeration and also the land was applied some organic manure. Wick Irrigation assemblies using 'Plastic Canes' and 'Wick' made up of cotton of 3mm diameter and about 20 cms long were used for the present experimentation. In order to install cotton wicks in the plastic canes a 3 mm thick steel wire was heated till it was able to penetrate the plastic cane fully and then using a thick needle, cotton wicks were installed in all the canes. Two sizes of Plastic canes having about 10 liters and 5.5 liters were used for the present study. The canes were fitted with wick at a distance of 5 cms from the bottom at the centre of sides for two types of configuration. In the first configuration the wicks were fitted on two sides of the canes and in the second configuration the wicks were fitted on all four sides at a distance of 10 cms and 15 cms from the bottom of the canes. Small canes were buried up-to depth of 15-17 cms from the bottom (i.e. 5-8 cms above ground level) and the big canes were similarly buried up-to depth of 18-20 cms from the bottom of the canes. All 'Wick Assemblies' were numbered for data recording and identification. A field experiment to ascertain the rate of flow through the wick was assembled and performed and the same was also recorded to test the suitability of the designed 'Wick Assembly' for large scale system. 'Wick Assemblies' (Large 24 Nos. + Small 24 Nos.) were then installed in the field (Plate 1).

Basins (9 Nos.) were also dug and planted for facilitating comparison of 'Wick Irrigation' to 'Basin Irrigation' method commonly resorted to by the farmers of the region. Seeds of Tomato (Solanum lycopersicum) and White Kidney beans (Phaseolus vulgaris) were planted around the 'Wick Assembly' and basins. The seeds of Tomato and Kidney Beans were purchased from market of Dhrangadhara city. Three to four numbers of seeds were used for plantation on one side around 'Wick Assembly' as the seeds that were purchased had 75 % of germination chances specified by the supplier/manufacturer. All the 'Wick Assembly' were filled with water with the help of a funnel and a filter (so that muddy water/ large suspended impurities do not enter the plastic canes) as the mouth of the plastic canes were small. The water to the experimental plot was brought using (manual labour) plastic buckets from an on-farm reservoir (Khet Talavdi). The plants/crops were given fertilizer as per the farmers' practice. Plate 2 shows a photographic view of plantation around small 'Wick Assembly'.

Plate 1 Photographic View of the Experimental Plot

2.3. Laboratory Tests

Laboratory experiments as per the methodology prescribed by the respective standards were performed to ascertain 'Textural soil classification' (In accordance with IS- 2720 Part- IV- 1985), 'Soil Permeability' by Falling Head Permeability test apparatus (In accordance with IS- 2720Part XVII – 1986), 'Rate of flow of water' in the air through the wick and the Moisture measurement of soil samples by the Gravimetric Method. The experiments were performed at Lukhdhirji Engineering College, Morbi.

Plate 2 Photographic view of plantation

2.4. Yield

The yield of White Kidney beans was calculated for a crop period of 85 days and for tomatoes the crop period was taken as up till 135 days. The water consumption was accordingly considered for the respective crop periods.

2.5. Wetting Front Movement

A 4.2 m long, 1.6 m wide, and 1.35 m deep open excavation (pit) was dug in the farm near the experimental plot to study the distribution of moisture beneath soil surface around the 'Wick Assembly', The assemblies were installed on the edge of the vertical side of the pit such that both the horizontal and vertical spread of moisture was visible.

In order to determine the percentage moisture content in the soil for studying the moisture distribution around the 'Wick Assembly', the soil samples were collected by spatula by making a grid of 15 cms originating from the neck of 'Wick Assembly'. The moisture content in the soil around the 'Wick Assembly' was determined by Gravimetric Method. In order to ascertain the movement of moisture into the soil due to 'Wick Assembly', soil sample were collected by auger and placed in an air tight self-locking plastic bags and kept in an air tight plastic box till it was taken to laboratory for moisture measurement.

2.6. Market Survey

For purchasing of Plastic canes and other materials, extensive survey on availability as well as on the price was conducted within the district. In order to find the market value of Tomato and White kidney beans a comprehensive market survey was done by inquiry in vegetable markets of Halvad city, Dhrangadhra city and Surendranagar city.

2.7. Benefit-Cost Analysis

Using the data of actual cost incurred for seeds, 'Wick Assembly', labour etc total expenditure per acre for irrigation with 'Wick Assembly' was worked out. Similarly, using the market survey method the monetary benefits accrued by selling the yield at market price the total benefits from the method of irrigation employed for the experimentation was computed. From these computations the benefit-cost ratio (B/C) was worked out.

III. RESULTS AND DISCUSSION

3.1. Quality of Irrigation Water and Soil:

The results of Soil Nutrient Test and Irrigation Water Quality Test are presented at Table- 1 and Table- 2 respectively. As per IS 1498- 1970 the soil of the experimental farm is classified as Fine Sand (SP-Poorly Graded Sand). The spreading of water beneath the ground level would be more vertical than horizontal in such type of soil. A fine texture soil exhibits more horizontal spreading of water as compared to coarse texture soil.

It is quite evident from the results that the experimentation was done with adverse quality of water and on an unfavorable land. The electrical conductivity (EC) of water is very high. Such water is absolutely unsuitable under normal situation. With such water, crops with high salt resistance can only be grown. If using such water the crops will always requires more and more water. The water has objectionable level of chloride too. Thus, the water can be rated as good to injurious depending upon the type of soil.

Table 1 Results of Soil Nutrient Test

Total Nitrogen	0.35 %
Available Phosphorous	7.0 Kg/Acre
Available Potash	112.0 Kg/Acre
pH	8.87
Electrical conductivity (EC)	0.38 milli- mhos/cm
Shulphar (S)	20.60 ppm
Zinc (Zn)	0.34 ppm
Ferrous (Fe)	7.46 ppm
Manganese (Mn)	13.64 ppm
Copper (Cu)	1.00 ppm

Table 2 Results of Irrigation water Quality Test

Parameters	Observed Values
Total Soluble Salts	1468 ppm
Carbonates (CO -3-)	00 ppm
Bicarbonates (HCO -3)	515 ppm
Chlorides (Cl -)	462 ppm
Sulphate (SO -4-)	39 ppm
Calcium (Ca ++)	44 ppm
Magnesium (Mg ++)	58 ppm
Sodium (Na+)	350 ppm
Sodium Adsorption Ratio (SAR)	8.0
pH	8.05
Electrical conductivity (EC)	2380 ro mhos/cm

By applying saline water with fitting irrigation management techniques, long-term sustainability in agricultural systems can be attained by practicing wick-irrigation, which was effectively demonstrated by the present study. Moreover, globally too, Saline water (up to 11 dS m-1) has been used productively in combination with commercial irrigation to irrigate a number of crops using drip irrigation; in view of that, there is no reason to believe that the same could not be done with wick irrigation.

Numerous characteristics make wick irrigation suitable for irrigation with low-quality water. One benefit of wick irrigation is its high water application efficiency. This can be matched up with surface irrigation schemes, which normally have low efficiency. Accordingly, less water and therefore less salt, is added to the soil. Secondly, the salt have a propensity to accumulate away from the active root-zone at the wetting front in close proximity to the soil surface. Due to the low discharge rates of wick irrigation systems consistent soil water content can be maintained in the soil and therefore variations and accumulation of salt concentration in the soil can be obviated.

3.2. Yield of Crops:

Figure 1 shows the yield as obtained by the experimentation. The yield of tomato plants under small 'Wick Assemblies' was less than large 'Wick Assemblies'. The yield of white kidney beans was also less in the case of small 'Wick Assemblies'. The increase in yield for small 'Wick Assemblies' was 27.30 % and for large 'Wick Assemblies' it was 54.6 % when compared to basin method of irrigation. The increased yield with wick irrigation method was a result of water being applied directly to the root and hence percolation loss and evaporation loss would have been far less making sure that more availability/ efficient use of water was made to the crops as compared to basin method of irrigation.

Table 3 shows the water consumption by the crops for Small 'Wick Assembly', Large 'Wick Assembly' and Basins. 82.43 % of water saving was attained using Small 'Wick Assembly', whereas, 80.48 % of water saving was attained using Large 'Wick Assembly' as compared to Conventional Basin Irrigation Method. The water consumption for all the methods was initially higher since the soil was in dry condition. With periodic watering the soil remained damp and thus the water consumption had declined till a water stress was felt by the plant. The water stress or the need of the water by the plant was also felt by the visual and feel appearance of the soil. It was seen that when the moisture deficit occurred in the field the rate of water flow through cane was increased to supply needed water to the crops. The osmotic pressure (i.e. soil tension) is the governing phenomenon for wick irrigation. The rise in water consumption during water stress and decline during sufficient moisture availability in the soil do suggest that the wick irrigation just like 'Pitcher Irrigation' is an auto-regulative mechanism capable of supplying water to plants as needed [8].

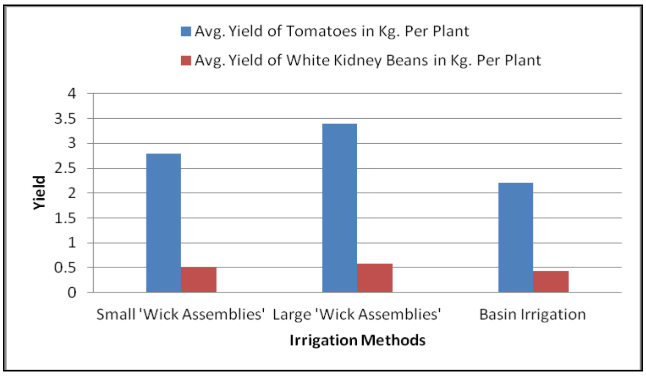

Fig.1 Yield of Crops

3.3. Wetting Front Advancement:

It was observed from the results of the moisture measurement that the maximum moisture content of the soil was 9.84 %. The lower moisture content near the surface could be attributed to evaporation from the soil. The Moisture Distribution in the soil is presented at Table 4. The moisture movement was more vertical than horizontal. The wetting pattern was like a balloon and extended to a horizontal distance of 21 cms and to a depth of 68 cms from the GL which is widely accepted as an effective zone for drawing out of moisture from the soil by the plants roots. The wetting front had started reducing after 120 hours and was completely gone after 9 days.

Table 3 Water Consumption by Crops

Small 'Wick Assembly' ***		Large 'Wick Assembly' $$$		Basin Irrigation ###	
No.	Irrigation Water Applied in Liters	No.	Irrigation Water Applied in Liters	No.	Irrigation Water Applied in Liters
S4/1	65.8	L4/1	59.2	B/1	288
S4/2	62	L4/2	52.7	B/2	288
S4/3	56.6	L4/3	57.4	B/3	288
S4/4	33.5	L4/4	40.5	B/4	288
S4/5	66.6	L4/5	61.5	B/5	288
S4/6	52.8	L4/6	45.9	B/6	288
S4/7	64.1	L4/7	71	B/7	288
S4/8	51.5	L4/8	57.5	B/8	288
S4/9	40.6	L4/9	52	B/9	288
S4/10	36.8	L4/10	47.9		
S4/11	33.6	L4/11	77.7		
S4/12	43	L4/12	51.2		
Total	606.9	Total	674.5	Total	2592
*** - 27 times Refilling of water into the canes at an interval of 3-4 days to restore level of 5.5 liters in the "wick Assembly'					
$$$ - 28 times Refilling of water into the canes at an interval of 3-4 days to restore level of 10 liters in the "wick Assembly'					
### - 38 watering over a period of 135 days ranging from 5 to 10 liters depending upon the requirement by visual inspection of soil and plant for water deficit by a farmer.					

The depth of burying the wick assembly into the soil could have a great effect on the wetting front. The deeper the wick assembly is installed in the farm the deeper is the movement of the water. For shallow rooted crops such as adopted in the present study the wetting front obtained was satisfactory.

Table 4 Moisture Distribution in Soil

Distance (Cms)	Depth (Cms)	% Moisture			
		Prior to Experim en-tation	After 24 Hours	After 72 Hours	After 144 Hours
0 C/L	0	--	7.25	7.02	1.96
	15	1.71	7.32	7.52	2.9
	30	4.54	7.98	8.12	3.95
	45	4.80	9.68	9.67	4.86
	60	5.14	--	9.61	5.7
15	0	--	7.04	6.94	1.78
	15	1.74	7.74	7.92	2.63
	30	3.28	8.35	8.33	3.45
	45	3.89	9.82	9.62	4.16
	60	4.98	--	9.84	5.24
60	0	--	2.35	4.1	1.66
	15	1.81	3.51	4.66	2.44
	30	1.83	4.59	7.02	1.96
	45	2.24	5.7	7.52	2.9
	60	3.36	--	8.12	3.95

The another significant conclusion that can be derived from the analysis of wetting front advance is that the distance between the wick assemblies used for the present study was such that the wetting front had never merged and thus a lower spacing would have been highly valuable in optimizing the use of agricultural land to achieve more yield.

The depth of placing the wick assembly has a great effect on the wetting front and thus it is imperative to optimize the moisture availability based on the wetting front for the respective soil. Farmers can test the wetting front movement in their respective farm before taking-up 'Wick Irrigation' for large-scale.

3.4. Sustainability and Economics:

Wick irrigation makes very proficient use of water since it delivers moisture directly to the plant's roots. Water poured into the canes seeps slowly into the soil, feeding the seedling or plant's roots with a steady supply of moisture. It could be understood that the water requirements in a wick irrigated field can be even less than those of a drip irrigated system due to the very low rate of water flow through the wicks, as well as reduced evaporation losses. Of course, growing crops in large areas requires buying quite a few canes! However, wick irrigation is still ideal for small farmers living in remote areas where vegetables are expensive and hard to come by. The cost of wick irrigation is also much less than that of drip or sprinkler irrigation methods. Wick pitcher irrigation is great for growing vegetables, for gardening and landscaping, and for growing plants in containers on patios or porches, where the canes is buried in the planter box. Limiting water delivery to the area where the plant is grown also dramatically reduces weed growth. The canes can be refilled every few days instead of requiring constant attention. All these facts do suggest that wick irrigation is sustainable.

The cost of plastic canes is affordable by majority of end users especially when it is procured from the wreckage market (used oil canes). Since this technology uses very less water it has a great potential for gaining popularity among farmers particularly in regions with scarce water. This technology does not call for any technical skill for its operation and maintenance. Adoption of this technology greatly enhances the economic benefit of the system and thus would also help uplift the farmers' economic condition. Wick Irrigation is also great for growing vegetables, for gardening and landscaping, and for growing plants in containers on doorways or porches.

The Benefit-Cost ratio per acre as compared to conventional farming for small 'Wick Assembly' was found to be 1.93 and that for large 'Wick Assembly' is was 2.34.

3.5. Limitation for Large Scale Adoption:

Large scale adoption of wick irrigation method requires some sort of arrangement for applying water to the canes at frequent interval. The same could be achieved with either having a flexible pipe network connected to a treadle pump or the source of irrigation water the canes can be directly filled requiring less labour. The manual watering of canes is a labour intensive task. The water requirement for the wick method of irrigation can be taken care of by harvesting the rain-water in a cistern. The harvested water can then be used for irrigation.

Wick irrigation is difficult to use in rocky soils. The installed cane that breaks during the growing seasons can disrupt the irrigation operation and reduce the productivity. The effective life of plastic cane would be greatly reduced with constant direct heat from the sun especially during summer season. Some plants with extended root systems are hard to cultivate using this technology. In some areas the availability of plastic canes may be an issue. The use of wick irrigation is only applicable to small-scale agriculture.

IV. CONCLUSIONS

The experimentation confirmed the fact that wick irrigation as an indigenous method can be successfully employed even for unfavorable land and water. Large 'Wick Assemblies' exhibits higher Benefit-Cost ratio as compared to Small 'Wick Assemblies'. The cost to be incurred for adopting these methods is quite less in comparison to drip irrigation and thus can be adopted by small and medium scale farmers. The use of small canes for wick irrigation is highly productive from the point of view of water saving in addition to economics. The movement of moisture within the soil was like a balloon and the horizontal spread of moisture was 21 cms, whereas, the vertical spread was to a depth of 68 cms from the GL. The use of wick irrigation is only applicable to small-scale agriculture. Wick irrigation is ideal for small farmers living in remote areas where vegetables are expensive and hard to come by.

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